DAMOCLES

DEBRISFALL ASSESSMENT IN MOUNTAIN CATCHMENTS FOR LOCAL END-USERS

Contract No EVG1 - CT-1999-00007

DETAILED REPORT OF CONTRACTOR FOR FIFTH PROGRESS MEETING

University of Padua, Italy

November 2002

DETAILED REPORT OF CONTRACTOR
FOR FIFTH PROGRESS MEETING

CONTRACTOR: UNIVERSITY OF PADOVA, DEPARTMENT OF LAND AND AGRO-FOREST ENVIRONMENTS – WATER RESOURCES DIVISION

RESPONSIBLE SCIENTIST: PROF. MARIO A. LENZI

ADDRESS: AGRIPOLIS, VIA ROMEA, 35020 LEGNARO (ITALY)

TELEPHONE: ++39-049-8272675
FAX: ++39-049-8272686
E-MAIL: marioaristide.lenzi@unipd.it

Summary.

During the period May-November 2002 the University of Padua's team has worked especially on the calibration and application of the 1-D MODDS model to both , the Sahùn catchment located in the Benasques Valley in the Spanish Pyrenees, and the Rudan catchment situated in the Northeastearn Italian Alps, in the Veneto Region. A preliminary definition of a debris-flow hard map for the Sahùn fan was obtained, helped by the IGME-Zaragoza's team in relation with acquisition of data input to the model. Other application of the model is related with simulations carried out on the Rudan catchment. In this case only possible overflowed cross-sections were outlined , in order to identified future mitigations measurements for debris flow control.

An important practical aspect of the DAMOCLES project in terms of technology transfer was carried out during the Training Course mounted by the Padova University on September 2002, in relation with the dissemination of the Workpackage 3 "Small debris flow impact model". Finally, several papers have been sent to international journals and presented in oral form in meetings.

Section 1: Objectives of the Reporting Period

According to the proposed work programme for DAMOCLES project the research team of the University of Padova (Mario A. Lenzi, Vincenzo D'Agostino, Carlo Gregoretti, Diego Sonda, Francesco Comiti and Luca Mao) had the following objectives included in the Workpackage WP3 "Development of a small basin debris flow impact model" and WP5 "Dissemination":

- Improvement of user-friendly graphics and data input-output of the Debris Flow Impact Model
- Organisation of the Damocles Training Course for Workpackage 3 (10-11 September 2002)
- Application of the Debris Flow Impact Model to the Rio Rudan catchment
- Calibration, validation and application of the Debris Flow Impact Model to the Sahùn Catchment (Spain).

- Preparation of papers, oral presentations; preparation of paper and reports for the Milan meeting and GISIG meeting (Milan, November 2002).

Section 2: Scientific/Technical Progress Made in Different Work Packages According to the Planned Time Schedule

Applications of 1-D MODDS model to Sahùn fan area

The 1-D MODDS was applied to the Sahùn catchment in order to individualise the overflow zones and the run-out distances of the overflow sediment discharges on the fan area. The purpose of the simulation was: a) the identification of critical sections including bridges and bends, b) the quantification of an extraordinary debris-flow magnitude, c) the mapping of a debris-flow hazard area within the fan.

Data on 40 cross-sections along the main stream and a DTM of the fan were elaborated by the Instituto Geologico y Miniero de España of Zaragoza, after a detailed topographic survey carried out during the year 2001.

The Sahùn basin is a small catchment in the Spanish Pyrenees south of the Pico de Cierco peak (2628 m.a.s.l.). The basin of Sahun stream (3.26 km^2) originates from the Southeastern slopes of the Tuca Cambra mountains (Pico Eriste). The drainage network comprises the main channel and numerous tributaries, many of which are ephemeral. The lowermost cross section was selected to coincide with the highest point of the alluvial fan (1200 m.a.s.l.).

The Sahùn main channel do not present any transversal or longitudinal consolidation control work. The vegetation cover present on the river bed may represent an important factor in case of flooding, causing flow diversion. Sediment source areas were identified in the field in order to understand different type of sediment contributions to the main stream.

Land use and vegetation cover classes of the Sahùn catchment are reported in Table 1.

Land use	**Area (km^2)**	**%**
Grass land	0.928	28.47
Wood of *Pinus mugo*	0.647	19.85
Mixed hardwood forest	1.685	51.68
Total	**3.260**	**100.00**

Table 1 – Land use and vegetation cover

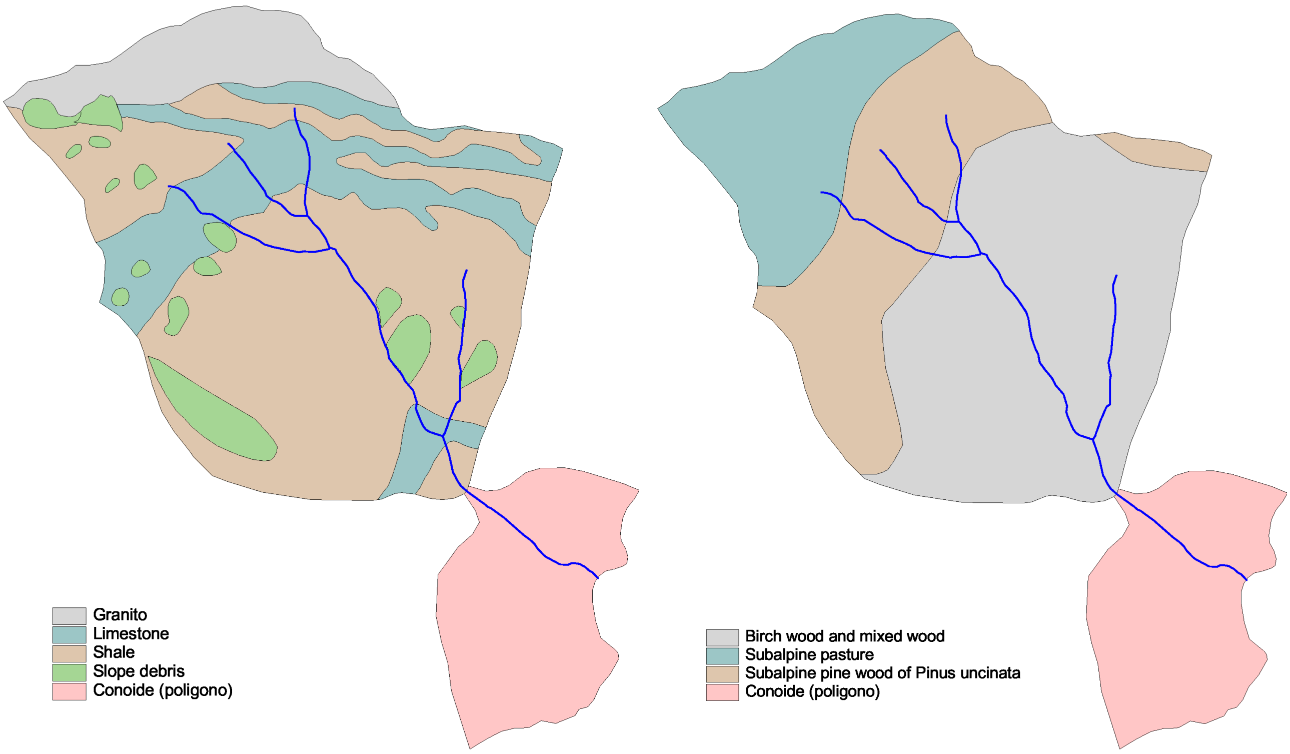

Figure 1 and 2 – Vegetation cover and geological map of Sahùn catchment.

The present morphology of the Sahùn watershed (Fig. 2) is mainly due to quaternary glaciers action and from successive fluvial processes. Main geological class of the basin are reported in Table 2.

Litological classes	**Area (km^2)**	**Area (ha)**	**%**
Granite	0.367	36.74	11.27
Grey limestone	0.714	71.40	21.91
Shale	1.922	192.28	58.98
Slope accumulations	0.255	25.59	7.84
Total	**3.260**	**326.00**	**100.00**

Table 2 –Geological classes in the Sahùn catchment .

Maximum flow discharge was assessed by using the Rational Method. Values worked out by the I.G.M.E. indicates a concentration time little shorter than 12 minutes. This evaluation was integrated by using Giandotti’s equation, which led to a concentration time of 21 minutes.

The principal parameters that describe the fan area of the Sahùn catchment are reported in Table 3. The value of Melton index analysed along with the average fan slope indicates that the fan have likely been originated by debris flow events; consequently, analogous mass transport events may still occur.

Parameter	Values
Area	0.80 km^2
Length	1.27 km
Average slope fan	13.00 %
Maximum altitude	1200.00 m.a.s.l.
Minimum altitude	1030.00 m.a.s.l.
Reach length	0.83 km
Melton index	0.74
Bridges number	2

Table 3 – Main characteristics of the Sahùn fan.

Quantification of the potential debris flow volume the basin would be able to generate was carried out by applying equations reported on Table 4.

A value of 40,000 m^3 for the debris-flow volume was considered for model application, based also on field surveys carried out along with the IGME's team.

Equations		Value
$M = 13600 A^{0.61}$	Takei (1986)	27953 m^3
$M = K_b A\, i$	Kronfellner-Kraus (1984)	79683 m^3
$M = 29100 A^{0.67}$	D'Agostino, Cerato, Coali (1996)	64205 m^3
$M = 211 A\, i^{1.3}$		57212 m^3
$M = \left(667 e^{-0.005A}\right) A\, i$		64139 m^3
$M = 45 A^{0.9}\, i^{1.5}\, (I.G.)$		50933 m^3
$M = 334 A\, i^{1.3}\, (I.T.)^{-0.6}$		90563 m^3
$M = 39 A\, i^{1.5}\, (I.G.)\, (I.T.)^{-0.3}$		49676 m^3
$M = 70000 A$	Marchi and Tecca (1996)	228200 m^3

Table 4 – Debris flow magnitude by using different equations.

Data used for the application of equations reported on Table 4 are the following (Table 5).

Parameter	Value
Basin area (A)	3.26 km^2
Main channel slope (i)	30.00 %
k_1	845
k	0.011
Geologic index (I.G.)	2.38
Transport index (I.T.)	1

Table 5 – Parameters adopted in the predictive equations of debris flow volume.

Different simulations highlighted an overflow cross section in correspondance to the first bridge (section 15), whilst the second bridge allows higher discharges to flow through (up to 586 m^3/s) without inducing lateral overflow. The simulations conducted with MODDS model showed the insufficiency of some other intermediate cross section too, in particular section 16.

Figure 3 shows the result of the simulation hypothesising a maximum debris-flow discharge of 197 m^3/s.

A primary hazard map was then elaborated, using Ikeya's method for the assessment of the maximum run-out distances corresponding to the overflowed debris flow volumes. This map (Fig. 4) should be consider provisional, since a better refined zoning requires more detailed field topography of the fan area.

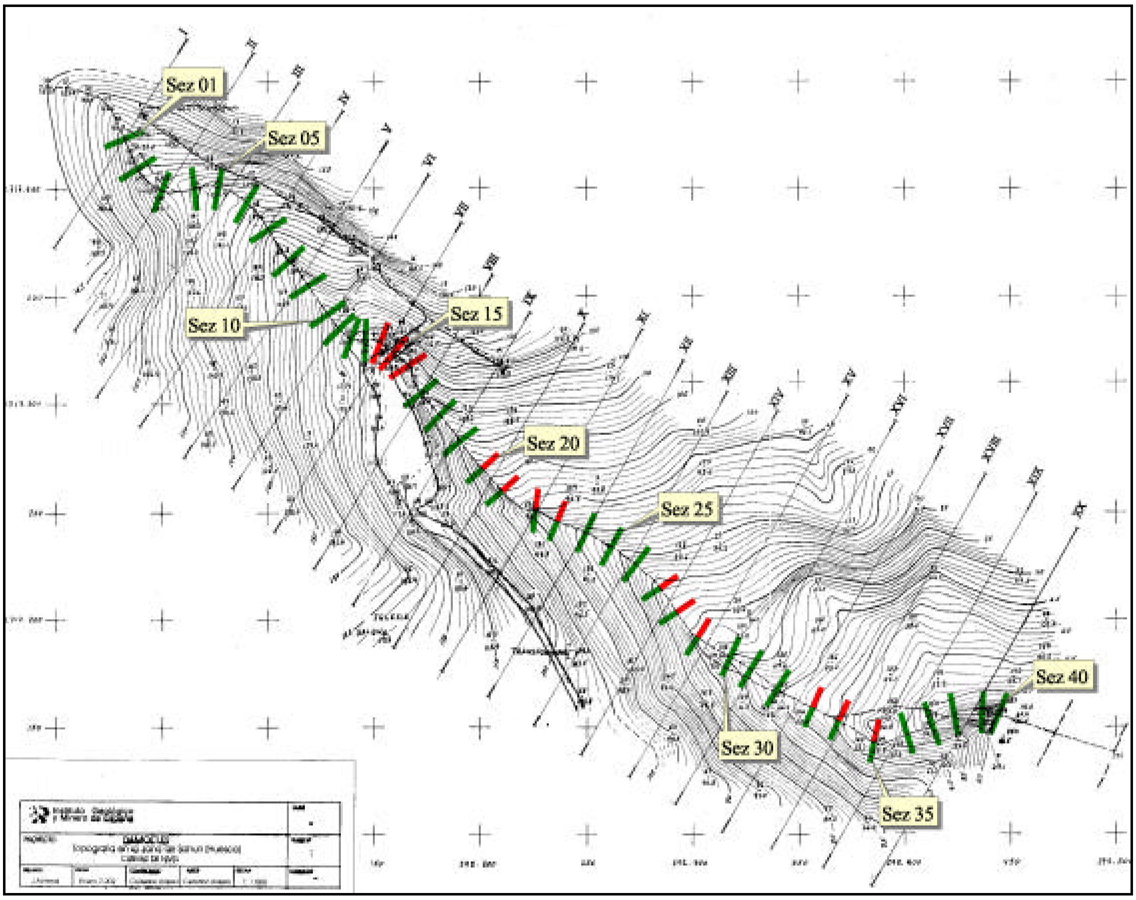

Figure 3 – 1-D MODDS output simulation carried out hypothesising 197 m^3/s of maximum debris-flow discharge and re-entering overflow solid material from first bridge. Red colour individualises overflow sections.

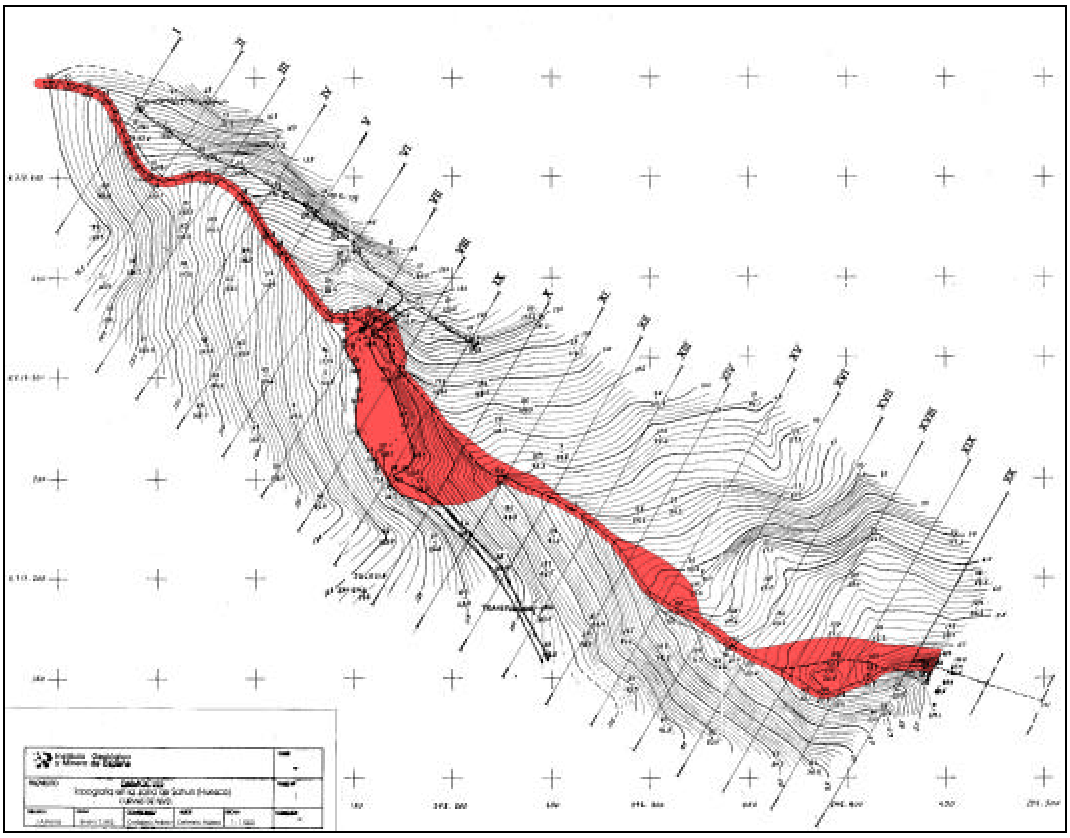

Figure 4 – Provisional hazard map of the Sahùn fan.

Applications of 1-D MODDS model to the Rio Rudan

The basin considered in this study is the Rio Rudan watershed, a small basin located in the Province of Belluno (Veneto Region). Its main morphometric characteristics are summarised in Table 6. The Rio Rudan basin is characterised by a dolomitic nature: high-sloped (subvertical) rocky cliffs make up the upper part along with a narrow, steep valley covered with talus deposit. Fluvial deposits cover most of the lower part, with a minor percentage of morainic, alluvial and fluvio-glacial materials (Fig. 5). The basins have a typical Alpine climate with annual precipitation ranging from 950 to 1300 mm, mainly occurs as snowfall from November to April. Runoff is usually dominated by snowmelt in May and June whilst summer and early autumn floods represent an important contribution to the flow regime.

The Rio Rudan stream take origins at 1900 m.s.m. at the foot of a fall, 15 m high, downstream a scree placed under the southern rock faces of Monte Antelao (3264 m.s.m.).

Catchment area	km^2	3.003
Average elevation	m.a.s.l.	1689
Minimum elevation	m.a.s.l.	801
Maximum elevation	m.a.s.l.	3264
Mean catchment gradient	%	98
Length of the main channel	km	4.02
Main channel mean gradient	%	34

Table 6 – Main morphometric characteristic of Rio Rudan catchment.

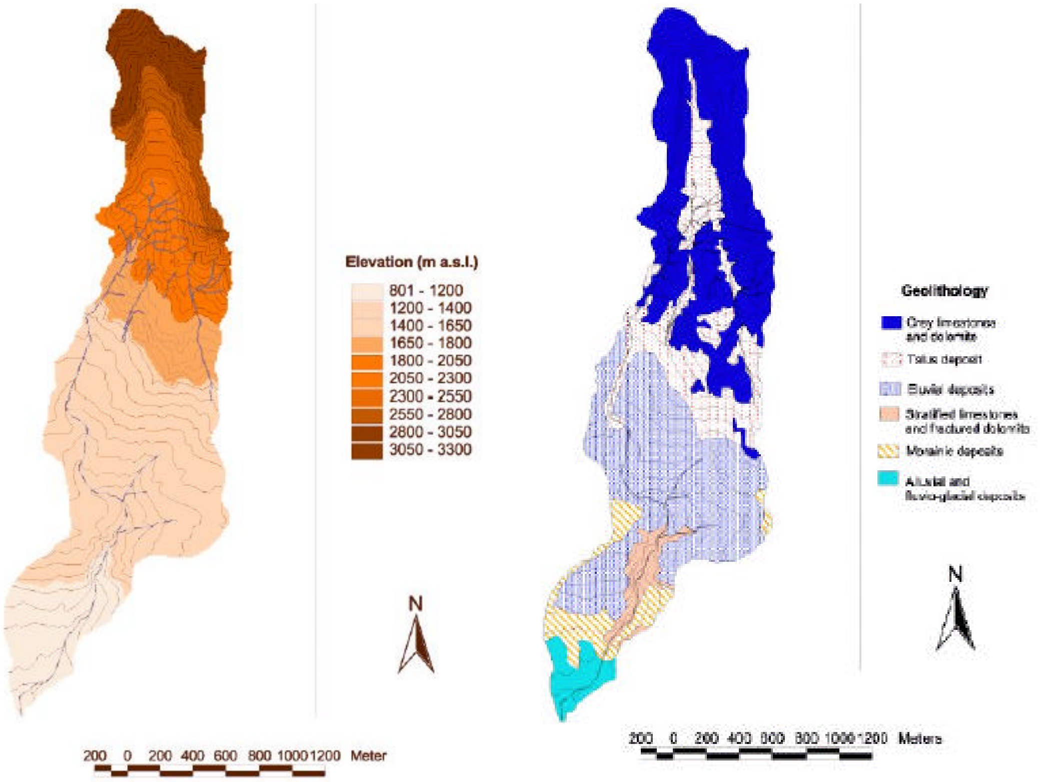

Figure 5 - Digital Elevation Model (DEM) and geologic map of the Rio Rudan basin.

In the lower part of the watershed the forest stands are made up by broadleaves such as beech (*Fagus sylvatica* L.) and ash (*Fraxinus excelsior* L.) mixed with spruce (fig. 6). Upslope, due to the high soil permeability, gradient and general slope instability, the Scotch Pine (*Pinus sylvestris* L.) predominates, blending with increasing patches of shrubs (*Pinus mugo* Turra, *Salix* spp.) moving toward the upper part of the basin (above 1800 m a.s.l.) where *Pinus mugo* forms a continuos belt under the dolomitic cliffs. In Table 7 are summarised the Rio Rudan land use.

Thick woodland	%	50.6
Sparse wodland	%	5.5
Shrubs	%	14.9
Grassland	%	1.2
Unproductive	%	27.8
Urban area	%	-

Table 7 – Land use of the Rio Rudan watershed.

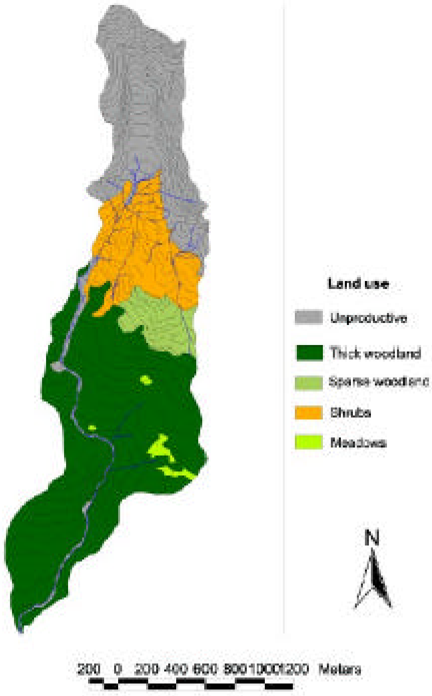

Figure 6 – The land use map of the Rio Rudan basin.

The upper part of this basin is characterized by the steep cliffs of the Antelao peak (3264 m.) and by a large scree slope. At this important accumulation of talus material triggering of debris flow usually occurs; debris-flow deposits located downstream of this zone indicate that debris flows are a recurring geomorphic process in this area.

The upper watershed portion also shows the presence of vast sediment sources areas, and the supply of mobilizable sediment is rarely a limiting condition for debris flow occurrence.

The Rio Rudan flows past a deep alluvial channel with high and steep banks (fig. 7), which are continuously eroded by mass transport phenomena except in the middle part of the basin, where the torrent flows over rock (fig. 8).

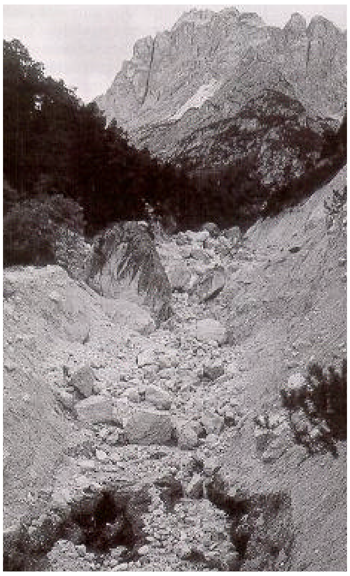 

Figure 7 and 8 – The Rio Rudan main stream: upper and medium reaches.

The average slope of the Rio Rudan between the waterfall and the National Road is 24%. The torrent is channelized 50 m upstream of the National Road n. 51; the banks here are concrete walls (2 m) and the cross section is rectangular. The average width of the cross section is 10 m and downstream of the bridge some transversal drop are present built to avoid bed erosion. The channelized reach of the torrent passes through the hamlet of Peaio (860 m.s.l.) before flowing into the Boite River at 800 m.s.l.m. The Melton index analysis shows that Rio Rudan can be considered a debris flow-generated fan.

The assessment of the liquid discharge was performed by using the S.C.S. method giving a value of 7.5 m^3/s for a 50-years return interval. Potential debris flow volume was evaluated by using several equations (tab. 8), and the most verisimilar value is considered to be 64,400 m^3.

Equations		Value
$M = 13600 A^{0.61}$	Takei (1986)	25597 m^3
$M = K_b A\, i$	Kronfellner-Kraus (1984)	86860 m^3
$M = 29100 A^{0.67}$	D'Agostino, Cerato, Coali (1996)	58285 m^3
$M = 211 A\, i^{1.3}$		66416 m^3
$M = \left(667 e^{-0.005A}\right) A\, i$		69733 m^3
$M = 45 A^{0.9}\, i^{1.5}\, (I.G.)$		68579 m^3
$M = 334 A\, i^{1.3}\, (I.T.)^{-0.6}$		105133 m^3
$M = 39 A\, i^{1.5}\, (I.G.)\, (I.T.)^{-0.3}$		65927 m^3
$M = 70000 A$	Marchi and Tecca (1996)	210000 m^3

Table 8 – Debris flow magnitudo values obtained with different empirical equations.

The routing of a debris flow down the channelized reach was simulated using the 1-D MODDS model; its peak solid discharge was evaluated from the peak liquid discharge (Hashimoto *et al.*, 1978). Considering the activity and the location of sediment sources, the peak discharge of the debris flow for the considered return time turns out to be around 112.5 m^3/s.

The simulation carried out with the 1-D MODDS model (fig. 9) shows that the channelized final reach have three critical sections: a) near the second bridge – section 30 – and b) on the left side of two sections, section 41 and 42. The total overflow volume is about 300 m^3.

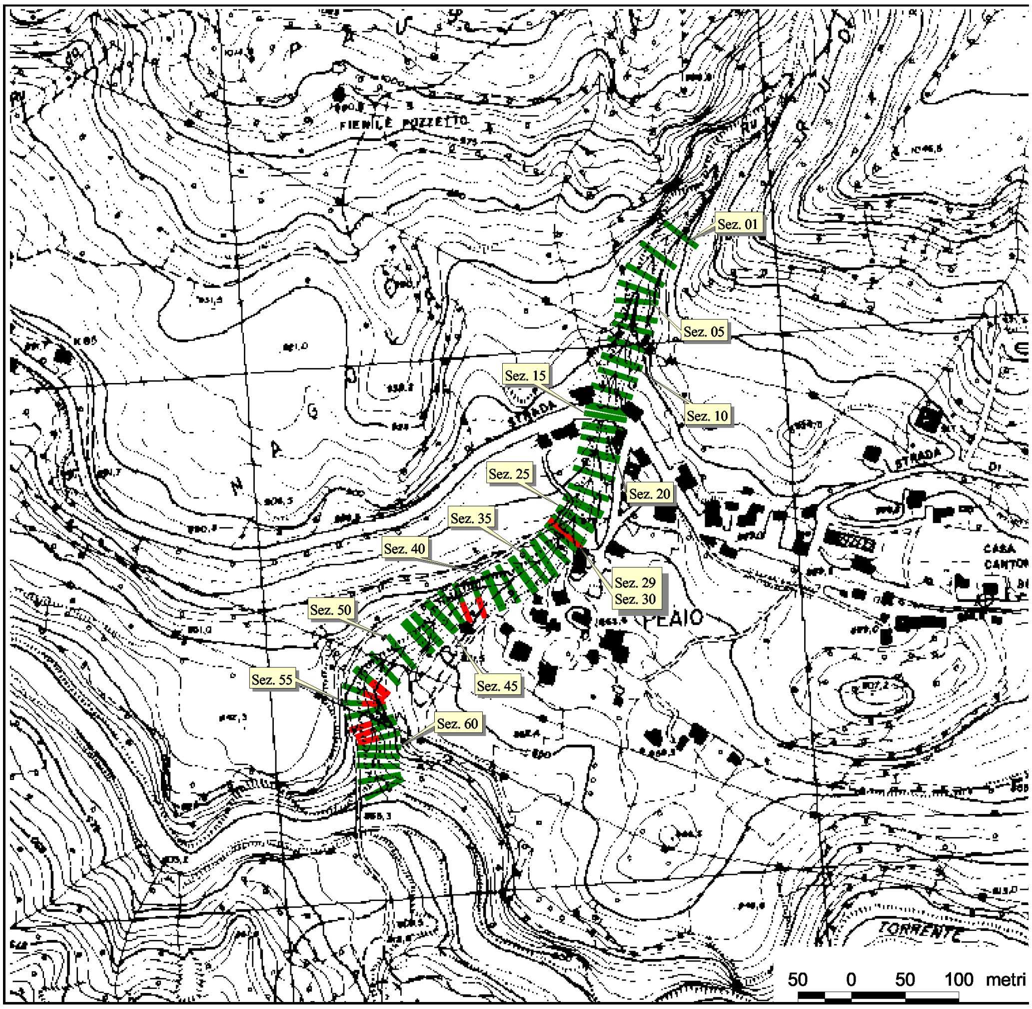

Figure 9 – 1-D MODDS output. Red colour individualize overflow sections.

Section 3: Milestones and Deliverables Obtained

During the last six months the following milestones and deliverables have been obtained:

- Small debris flow impact model, DEFLIMO, integrated within a GIS (Deliverable D7).
- MODDS, DDFM and DEFLIMO model's applications to test areas A (Italian catchments) and B (Spanish Pyrenees catchment).
- A report of the training course oriented to End-Users, related with the application and implementation of the Work Package 3 (Small Basin Debris Flow Impact Model).
- End-users trained in project technologies (Deliverable D10).

Section 4: Deviations from the Work Plan and/or Time Schedule and Their Impact on the Project

There has been no deviations from the work plan during the reporting period; according to the proposed activities, the planned goals have been fulfilled. All the deliverables foreseen in our work-packages have been already sent to the Coordinator.

Section 5: Coordination of Information between Partners and Comunication Activities

We have not coordination problems both with the General Coordinator of the Project and with the other partners and teams.
A joint-work with IGME –Zaragoza's team was carried out, concerning the Sahùn catchment characterization, data exchanges and data input for the 1-D submodel MODDS and for the application carried out on the Sahùn fan area in order to identified the debris-flow hazard map.
The demonstration linking of WP2 and WP3 models with the Milano-Biccoca's team was started
Members of the UNIPD's team have participate in different meetings, presenting results from the DAMOCLES Project:

- A training course related with the application and implementation of the Work Package 3 (Small Basin Debris Flow Impact Model) was organized on the **campus** of the Agricultural Faculty of the University of Padova (**Agripolis**) at Legnaro (PD). Sessions were planned in two days; Tuesday 10, 2002, was dedicated to the presentation of the 1-D and 2-D Models and also to discuss the different types and characteristics of gully-channelised debris flow, limits of the two models, field of applications and data set inputs requirements. A video showing triggering, propagation and sedimentation of a debris flow was used to facilitate the exchange of ideas between end-users (geologists, practicing engineers, forestry managers, technicians). A typical practical-individual technical session using 10 dedicated-PC was carried out on the GIS laboratory ,Wednesday 11, 2002. A report titled *Methodological guide: case studies and applications* was prepared and given to all participants. The report is also available as PDF file and can be consulted visiting the project website. A detailed list of the 16 participants attended the course is reported on the Annex 1. This includes 4 participants coming from the Torrent Control Agency of the Autonomous Province of Trento (2 practicing engineers, 1 general manager and the responsible of the GIS and Geoinformatic Division); 2 participants coming from regional planning authorities of the Veneto Region ("Direzione Difesa del Suolo" and "Associazione Italiana di Idronomia"); 1 participant coming from the "Struttura Rischi Idrogeologici" of the Lombardia Region and 2 participants of the University of Milano Bicocca; 1 participant coming from a Spain End-user: the "Instituto Geològico y Minero" of Zaragoza. Other participants as geologists, consultants, junior geologist working in private companies and Ph.D students also attended the course. Names of the invited participants were suggested by our End-users because most of them are working as consultants with them or with other regional authorities and geological surveys.

- National Symposium *Gestione Integrata dei Bacini Idrografici,* organized by Associazione Italiana di Idronomia, University of Padua and University of Bari; Bari, October 2-3, 2002.

Section 6: Difficulties Encountered at Management and Coordination Level and Proposed/Applied Solutions

No difficulties have been found at management and coordination level.

Section 7: Plan and Objectives for the next period

During the next period, November 2002-February 2003, the work plan of the UNIPD's team is the following:

1. To complete with Milano-Bicocca's team, the demonstration linking of WP2 and WP3 models.
2. To attend the GISIG meeting at Milan in November 2002.
3. To prepare papers for international journals and conferences. The UNIPD's team will attend the XXX IAHR Conference at Thessaloniki, Greece, 24-29 August 2003, and the next EGS Assembly at Nice , April 2003.
4. To write the final Project Report, cost statement, in January-February 2003.

Section 8: Publications

Lenzi, M.A., D'Agostino, V., Gregoretti, C., Sonda, D., Guarnieri, A., Comiti F. & Mao, L. 2002. *Modellistica della propagazione delle colate detritiche e della sedimentazione nei conoidi alluvionali: guida metodologica, casi di studio ed applicazioni*. DAMOCLES Training Activities, September 10-11, 2002, University of Padova: pp. 74.

Lenzi, M.A. 2002. Stream bed stabilization using boulder check dams that mimic step-pool morphology features in Northern Italy. Geomorphology 45, 243-260.

Lenzi, M.A. & Mao, L. 2002. Analisi del contributo del trasporto solido in sospensione alla produzione di sedimento del bacino del Rio Cordon nel periodo 1986-2001. Quaderni di Idronomia Montana n. 21: 1-18, (in press).

Lenzi, M.A., 2002. Debris-flow hazard assessment using numerical models and GIS. ECO-GEOWATER Workshop "GIS and Natural Hazards" ; Milano, 18th - 22th November 2002; pp. 18.

Lenzi, M.A., D'Agostino, V., Gregoretti, C. & Sonda, D. 2003. A simplified numerical model for debris flow hazard assessment: DEFLIMO. *Proceedings 3° International Conference Debris-Flow Hazards, Mitigation*, Davos, Switzerland, September 10-12: pp. 12, (sent for publication)

Section 9: References

Arattano, M., Marchi, L., Deganutti, A.M., Grattoni, P., and Godone, F., *Field monitoring and data analyses in the Moscardo basin*, European Project Debris Flow Risk, Environment and Climate Programme 1994-98, Contract no. ENV4-CT96-0253, Final Report, 2.5.1-2.5.39, 1999.

Bertotto, B., *Le colate detritiche nei bacini dell'Alto Adige*, Degree thesis in Environmental and Forest Science, University of Padova, 124 pp., 2000.

Bovis, M.J., and Jakob, M., *The role of debris supply conditions in predicting debris flow activity*, Earth Surface Landforms and Processes, 24, 1039-1054, 1999.

Brochot, S., *Etude hydraulique de l'Arc de Maurienne (de Modane à l'Isère)* - Estimation des apports sédimentaires des torrents affluents, Cemagref - Groupement de Grenoble, 49 p. plus annexes, 1998.

Cazorzi, F., Watershed Oriented DIgital TErrain Model - Users Guide Version Windows 95, Lab.

Cunge J.A., On the subject of a flood propagation computation method (Muskingum method), J. Hydraulic Res., 7(2), 205-230, 1969.

D'Agostino, V., Cerato, M., and Coali, R., *Il trasporto solido di eventi estremi nei torrenti del Trentino Orientale*, Int. Symp. Interpraevent 1996, vol. 1, 377-386, 1996.

D'Agostino V., Il trasporto solido di eventi estremi nei torrenti del Trentino Orientale, International Congress Interpraevent 1996, Garmisch-Partenkirchen, Austria, vol. I , 377-386, 1996.

Gregoretti C., *Estimation of the maximum velocity of a surge of debris flow propagating along an open channel"*, Proceedings of the Internationales Symposion INTERPRAEVENT 2000 – Villach, Band 3, 99-108, 2000.

Henderson F.M., *Open channel flow,* chap.9: Flood routing, macmillian, New York, 1966.Hungr, O., Morgan, G.C., and Kellerhals, R., *Quantitative analysis of debris torrent hazard for design of remedial measures*, Canadian Geotechnical Journal, 21(4), 663-677, 1984.

Ikeya, H. 1981. A method of designation for area in danger of debris flow. *Symp. on Erosion and Sedimetation in Pacif Rim Steepland*, IAHS-AIHS pub. N.132: 576-588.

Laigle D., Marchi L., *Example of mud/debris-flow hazard assessment, using numerical model*, Proceedings of Conference on Debris-Flow Hazards Mitigation: Mechanics, Prediction, and Assessment, Wieczorek & Naeser eds., Balkema, Rotterdam, 417-424, 2000.

Marchi, L., and Tecca, P.R., *Magnitudo delle colate detritiche nelle Alpi Orientali Italiane*. Geoingegneria Ambientale e Mineraria, 33(2/3), 79-86, 1996.

Kronfellner-Kraus, G., *Quantitative estimation of torrent erosion*, International Symposium on Erosion, Debris Flow and Disaster Prevention, Tsukuba, Japan, 107-110, 1985.

O'Brien, J.S. and Julien P.Y., *Phisical Propeerties and Mechanics of Hyperconcetrated Sediment Flows"*, Delineation of Landslide, Flash flood, and Debris flood Hazards in Utah, Utah State University, Utah Water Research Lab., Logan, Utah, 260-279, 1984.

Piccoli, E., *Definizione delle aree di pericolo in relazione a fenomeni di debris flow: il caso di studio del Rio Lenzi*, Degree thesis in Environmental and Forest Science, Univ. of Padova, 221 pp., 2000.

Rickenmann, D., Weber, D. *Flow resistance of natural and experimental debris-flows in torrent channels*", Proceedings of Conference on Debris-Flow Hazards Mitigation: Mechanics, Prediction, and Assessment, Wieczorek & Naeser eds., Balkema, Rotterdam, 245-254, 2000.

Scheuringer, E., *Ermittung der massgeblichen Geschiebefracht aus Wildbach-Oberlauten, Wildbach und Lawinenverbau*, 52, 109, 87-95, 1988.

Sonda, D. 2001. Valutazione della pericolosità idrogeologica sui conoidi alpini. Ph.D Thesis, Department of Land and Agroforest Environment, University of Padova: pp. 256.

Spreafico, M., Lehmann, Ch., and Naef, O., *Recommandations concernant l'estimation de la charge sédimentaire dans les torrents*, Groupe de travail pour l'hydrologie opérationnelle, 1999.

Takei, A., *Interdependence of sediment budget between individual torrents and a river-system*, Int. Symp. Interpraevent 1984, Villach, Austria, vol. 2, 35-48, 1984.

Van Steijn H., *Debris-flow magnitude-frequency relationships for mountainous regions of Central and Northwest Europe*, Geomorphology, 15, 259-273, 1996.

Thouret, J.-C., Vivian, H., and Fabre, D., *Instabilité morphodynamique d'un bassin-versant alpin et simulation d'une crise érosive (L'Eglise-Arc 1800, Tarentaise),* Bull. Soc. géol. France, 166(5), 587-600, 1995.

Weinmann, P. E. and Lauerson, E. M., *Approximate flood routing methods: A review,* J. Hydr. Div., ASCE, 105(12), 1521-1536, 1979.